

STIMULUS CONTROL OF BEHAVIORAL HISTORY

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Pigeons were exposed to two different reinforcement schedules under different stimulus conditions in each of two daily sessions separated by 6 hr (Experiments 1 and 2) or in a single session (Experiment 3). Following this, either a fixed-interval (Experiment 1) or a variable-interval schedule (Experiments 2 and 3) was effected in both stimulus conditions. In the first two experiments, exposure to fixed-ratio or differential-reinforcement-of-low-rate schedules led to response-rate, but not pattern, differences in subsequent performance on fixed- or variable-interval schedules that persisted for up to 60 sessions. The effects of reinforcement-schedule history on fixed-interval schedule performance generally were more persistent. In Experiment 3, a history of high and low response rates in different components of a multiple schedule resulted in subsequent response-rate differences under identical variable-interval schedules. Higher response rates initially occurred in the component previously correlated with high response rates. For 3 of 4 subjects, the differences persisted for 20 or more sessions. Previous demonstrations of behavioral history effects have been confined largely to between-subject comparisons. By contrast, the present results demonstrate strong behavioral effects of schedule histories under stimulus control within individual subjects.

Key words: behavioral history, stimulus control, within-subject comparison, variable-interval schedules, fixed-interval schedules, fixed-ratio schedules, differential-reinforcement-of-low-rate schedules, key peck, pigeon

The experimental analysis of behavior has focused on temporally proximal (current) contingencies that mask, overcome, or obtund the effects of temporally distal (past) ones. If current variables fully account for current behavior, there is no need to specify past experiences. Such an accounting, however, often is not the case. Variability in responding, for example, sometimes results in part from historical variables; the expression "history effects" connotes sources of control over present behavior that have not been eliminated by refinements of proximal contingencies and thus confound the obtained functional relations between responding and proximal contingencies.

Sidman (1960) suggested that historical variables can be studied systematically by arranging certain experiences and then evaluating the effects of those experiences on subsequent performance. For example, Wei-

ner (1964, 1965, 1969) found that humans responded differently under identical fixed-interval (FI) schedules of reinforcement depending on whether they previously responded on fixed-ratio (FR) or differential-reinforcement-of-low-rate (DRL) schedules. Responding under FI schedules mirrored the high or low rates previously engendered. Thus, a single schedule controlled different response rates solely as a function of prior schedule experience.

Similar effects of schedule history on FI responding have been reported with non-human subjects. Urbain, Poling, Millam, and Thompson (1978) first exposed groups of rats to either FR or DRL schedules for 50 sessions. Subsequent exposure to FI schedules for 15 sessions resulted in effects similar to those reported by Weiner: FI responding mirrored the high or low response rates that developed under the previous condition. Wanchisen, Tatham, and Mooney (1989) systematically replicated the findings of Urbain et al. (1978) and showed that FI performance of rats differed as a result of the presence or absence of a history of responding on variable-ratio (VR) schedules. Wanchisen et al., however, pointed to differences in human and rat FI performance that led them to caution that direct comparisons of schedule control of these species' behavior are premature.

Variable-interval (VI) schedule perfor-

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mance has been reported to be less affected by schedule history than is FI schedule performance. Poling, Krafft, and Chapman (1980) trained groups of rats on either FR or DRL schedules for 47 to 51 sessions. Response rates were considerably higher under the FR than under the DRL schedule. Then they exposed all of the rats to a VI 1-min schedule for 43 to 47 sessions. The VI response rates of the two groups tended to converge over sessions; the mean rates of the group with a history of FR responding were only slightly higher than those of the group with the DRL history. However, Poling et al. did not provide individual-subject data. Nader and Thompson (1987) found that groups of pigeons trained on FR or DRL schedules for 50 to 70 sessions subsequently exhibited equivalent response rates on a VI schedule after 4 to 23 sessions.

Each of the experiments described thus far suggests the influence of prior schedule experience on current responding by using a procedure in which different rats or humans were trained on different schedules and then were switched to the same schedule. Several limitations to this procedure, which are considered below in greater detail, provided the impetus for the present experiments: Variables such as reinforcement rate were not constant between the training and testing schedules, comparisons of different histories were limited to those between different groups of subjects, and almost all of the studies conducted with nonhumans used rats as subjects.

Several of the studies of schedule-history effects have used FR or DRL training schedules in which reinforcement rate was not equated in the two schedules. Nevin (1974) showed that different rates of reinforcement of responding on VI schedules differentially affected subsequent responding during extinction. As a result, subsequent changes in behavior in these studies of behavioral history effects could result in part from differences in reinforcement rate in the training schedules. In addition, reinforcement rate in the training and subsequent FI or VI schedules often is not equated (but cf. Urbain et al., 1978). Nader and Thompson (1987) speculated that the presence of only weak history effects in their experiment may have resulted from a change in response key location and color when the VI schedule was introduced. These

are salient stimulus changes, as are changes in reinforcement rate (e.g., Commons, 1979); both types of stimulus changes may be sufficient to diminish the historical effects of the previous schedule.

In all of the experiments with nonhumans described above, different groups of subjects were provided different histories, thereby permitting only across-subject comparisons. When individual subjects were trained under different schedules (e.g., Weiner, 1969), exposure was sequential, with each schedule in effect for a number of sessions (e.g., DRL-FI-FR-DRL). Weiner suggested that certain schedules early in a sequence can override the effects of subsequent schedules with human subjects; for example, "... FR responding will not generate high rate performance under fixed-interval contingencies if subjects have a history of DRL responding" (1969, p. 363). Thus, the use of group designs to study reinforcement-schedule history effects seems to reflect a concern about "contaminating" subjects with multiple experiences. Because individual differences in response rates on schedules of reinforcement can be large, a technique for comparing the historical effects of different reinforcement schedules within individual subjects would be a useful development.

Strong effects of schedule history have been obtained with rats and humans when FI schedules have been used to assess history effects. Given the extensive use of pigeons in studies of reinforcement-schedule performance, it is surprising that only one study of reinforcement-schedule history effects has been conducted using pigeons as subjects (Nader & Thompson, 1987). The results of that study are difficult to relate to the others conducted with rats and humans because VI rather than FI performance was the index of historical effects and the procedures differed from other studies of behavioral history.

In the present experiments, parallel, rather than sequential, histories of responding by pigeons were established under different reinforcement schedules, in which each schedule was correlated with distinct stimuli. The subsequent effects of these parallel experiences on either FI or VI performance were examined. The parallel history procedure permitted an assessment, within individual subjects, of performance under FI or VI schedules

in the presence of stimuli historically correlated with different positive reinforcement schedules.

EXPERIMENT 1

Experiment 1 investigated the effects of prior parallel experience on FR and DRL schedules on subsequent FI performance.

METHOD

Subjects

Three experimentally naive White Carneau pigeons were maintained at 80% of their free-feeding weights. Water and health grit were freely available in the home cage.

Apparatus

Three nearly identical operant conditioning chambers were used. The work area of each chamber was 33 cm by 35 cm by 35 cm. A response key was centered on an aluminum work panel 25.5 cm from the floor. The key was activated by a minimum force of 0.14 N. The response key in each chamber could be transilluminated red, green, amber, blue, or white. General illumination was provided by a houselight that was on throughout the session except during reinforcement.

Reinforcement was 3-s access to mixed grain in a grain hopper located behind an opening (5 cm square) on the midline of the work panel. The lower edge of the opening was 8.5 cm from the floor. During reinforcement, the food hopper was illuminated by a white light when it was raised. A ventilating fan masked extraneous sounds. A PDP 8a® computer using Supersked® software controlled the experimental operations and recorded data. A Gerbrands cumulative recorder (Model C-3) also was used.

Throughout the experiment, the interior of each chamber was either black or white. To create a black chamber, black posterboard panels were inserted to cover the interior walls and ceiling of the chamber. Openings were cut in the posterboard for the keylight, food aperture, houselight, and exhaust fan port. A reusable gum adhesive held the panels in position. To create a white chamber, the posterboard panels were removed, leaving the white painted walls of each chamber exposed; the work panel was metallic gray.

Procedure

Magazine training and hand-shaping of the key-peck response occurred in the presence of the stimuli to be correlated with the FR schedule; thereafter, two daily sessions occurred. In one session, a DRL schedule was in effect, and in the other an FR schedule was used. The sessions were separated by 6 hr, during which time each pigeon was returned to its home cage. The order of the two daily sessions (FR or DRL) was determined by a coin toss, with the restriction that the same order could not occur for more than 3 consecutive days. Keylight colors were red, green, or amber in the different black chambers when the FR schedule was in effect and were blue, white, or green in the different white chambers when the DRL schedule was in effect.

In an effort to equate reinforcement rate in the two training conditions, the value of the DRL schedule in the immediately preceding session determined the value of the next FR schedule. The initial DRL schedule value was 1 s; this was increased over several sessions. The mean interreinforcer interval (IRI) (session time – reinforcer access time/number of reinforcers) was calculated for each DRL session. The subsequent FR requirement was set before each session to yield a rate of reinforcement equal to that in the immediately preceding DRL session. FR response rates increased rapidly over the first few sessions; therefore, the FR requirement had to be increased progressively over these sessions. To prevent ratio strain in the FR condition, the DRL schedule value was adjusted occasionally during the early training sessions. For each subject, approximately 20 days prior to the completion of the training condition when reinforcer rates in the two components appeared stable on visual inspection, the FR and DRL values were set for the remainder of the training condition. The final values for the FR and DRL schedules for Pigeons 634, 4214, and 4265 were 56 responses and 4 s, 40 responses and 4 s, and 64 responses and 6.25 s, respectively. The FR and DRL schedule training condition, hereafter described as the differential condition, was in effect for 50 sessions for Pigeon 4214, 51 sessions for Pigeon 4265, and 52

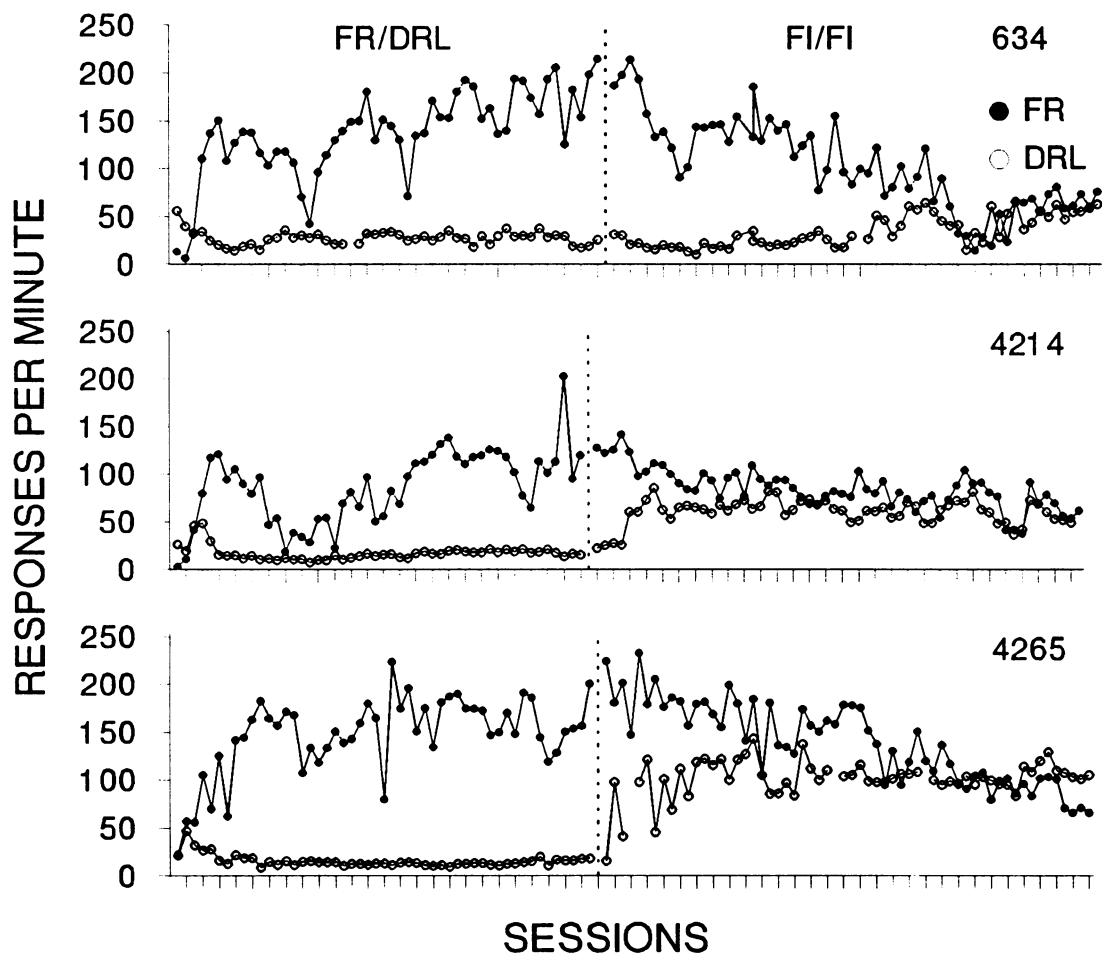


Fig. 1. Response rates for each subject in each session of Experiment 1. The labels at the top of the graph indicate the schedules in effect in the two conditions. The FR/DRL label identifies the differential condition, and the FI/FI label identifies the nondifferential condition. In the FI/FI condition, the data are identified by the schedule previously in effect in the same stimulus condition during the training condition.

sessions for Pigeon 634. Fifty sessions were considered to be adequate to establish schedule and stimulus control of behavior (cf. Urbain et al., 1978).

Following the differential training condition, a nondifferential condition was in effect for 60 sessions. This number of sessions was arbitrary but was considered adequate to observe the effects of the nondifferential schedules. The nondifferential condition was identical to the differential condition except that an FI schedule occurred in both daily sessions. The keylight and chamber colors remained as they were in the differential condition, but now the schedules correlated with these stimuli were identical. For each subject, the FI values were determined by examining the mean IRI

of each of the final 10 sessions of the differential condition. From these 10, the five most similar to one another were averaged to yield the IRI used in the nondifferential condition. These values were 19, 21, and 24 s for Pigeons 634, 4214, and 4265, respectively.

In both the differential and nondifferential conditions, sessions ended after 30 reinforcers and were conducted 7 days per week.

RESULTS

The mean IRIs (with ranges in parentheses) for the last 10 FR and DRL sessions for Pigeons 634, 4214, and 4265, respectively, were (in seconds) 19.5 (17.0 to 24.5) and 21.5 (17.1 to 33.4), 25.1 (19.3 to 30.1) and

22.4 (18.0 to 29.0), and 24.2 (20.1 to 37.1) and 21.4 (16.4 to 30.5). Thus, the reinforcement rates in the FR and DRL schedules were approximately equal.

Figure 1 shows the response rates of each pigeon for each session of the experiment. During all but the first few sessions of the differential training condition (labeled FR/DRL in Figure 1), response rates were higher by a factor of at least 4.5 when the FR schedule was in effect than when the DRL schedule was in effect. Following introduction of identical FI schedules in both daily sessions (labeled FI/FI), response rates remained higher in the presence of the stimuli previously correlated with the FR schedule. These latter response rates were exceeded by those in the presence of the stimuli previously correlated with the DRL schedule only after 41, 25, and 18 sessions for Pigeons 634, 4214, and 4265, respectively. The response rates tended to converge with continued FI exposure; that is, rates in the presence of the former FR and DRL stimuli decreased and increased, respectively. Despite this convergence, response rates in the former FR condition exceeded those in the former DRL condition during 55, 52, and 45 of the 60 nondifferential sessions for Pigeons 634, 4214, and 4265, respectively.

One index of response patterns is the quarter-life measure (Herrnstein & Morse, 1957). In this and the next experiment, quarter-life values were calculated as the proportion of the FI required to emit .25 of the responses in that interval. Therefore, for any FI schedule, quarter-life values of .25 suggest steady rates throughout the IRI and values exceeding .25 suggest scalloping or break-and-run patterns. Table 1 shows quarter-life values during Sessions 5, 25, and 50 of the nondifferential condition and mean quarter-life values for the last six nondifferential sessions. These data are representative of response patterns throughout the experiment. In each case, the values are above .25, indicating that responding across the FI was not constant. Inspection of cumulative records suggested a mix of scalloped and break-and-run FI patterns across and within subjects. The quarter-life measures indicate that systematic differences in the FI response patterns as a function of FR or DRL training did not occur after the first few sessions. However, over the 60 FI sessions, quarter-life values in-

Table 1

Mean quarter-life values in each component of the multiple FI FI (nondifferential) condition.

| Subject | FI schedule following FR or DRL training | Session | | | |
|---------|--|---------|-----|-----|---------|
| | | 5 | 25 | 50 | Final 6 |
| 634 | FR (FI) | .59 | .66 | .64 | .69 |
| | DRL (FI) | .48 | .69 | .70 | .73 |
| 4214 | FR (FI) | .53 | .53 | .55 | .63 |
| | DRL (FI) | .62 | .69 | .73 | .72 |
| 4265 | FR (FI) | .49 | .57 | .64 | .77 |
| | DRL (FI) | .47 | .60 | .65 | .66 |

creased in both conditions, suggesting increased control by the FI schedule.

EXPERIMENT 2

Experiment 2 examined the effects of parallel histories of responding on FR and DRL schedules on subsequent responding maintained by a VI schedule of reinforcement.

METHOD

Subjects and Apparatus

Three experimentally naive White Carneau pigeons were maintained at 80% of their free-feeding weights. Water and health grit were freely available in the home cage. The apparatus was the same as in the first experiment.

Procedure

The procedure was the same as in the first experiment except that the schedule in effect during the nondifferential condition was a VI rather than an FI.

The values of the FR and DRL schedules in effect for the last 20 sessions of the differential condition for Pigeons 2221, 4226, and 4238, respectively, were 60 responses and 6.75 s, 64 responses and 5.25 s, and 40 responses and 6.5 s. The differential condition was in effect for 50 sessions for each pigeon, and the nondifferential condition was in effect for 60 sessions for each pigeon.

The mean IRIs for the VI schedules were generated using the procedure described in Experiment 1 for determining FI schedule values. A constant-probability progression (Fleshler & Hoffman, 1962) was used to generate the temporal distribution of reinforcers. Each distribution contained 30 in-

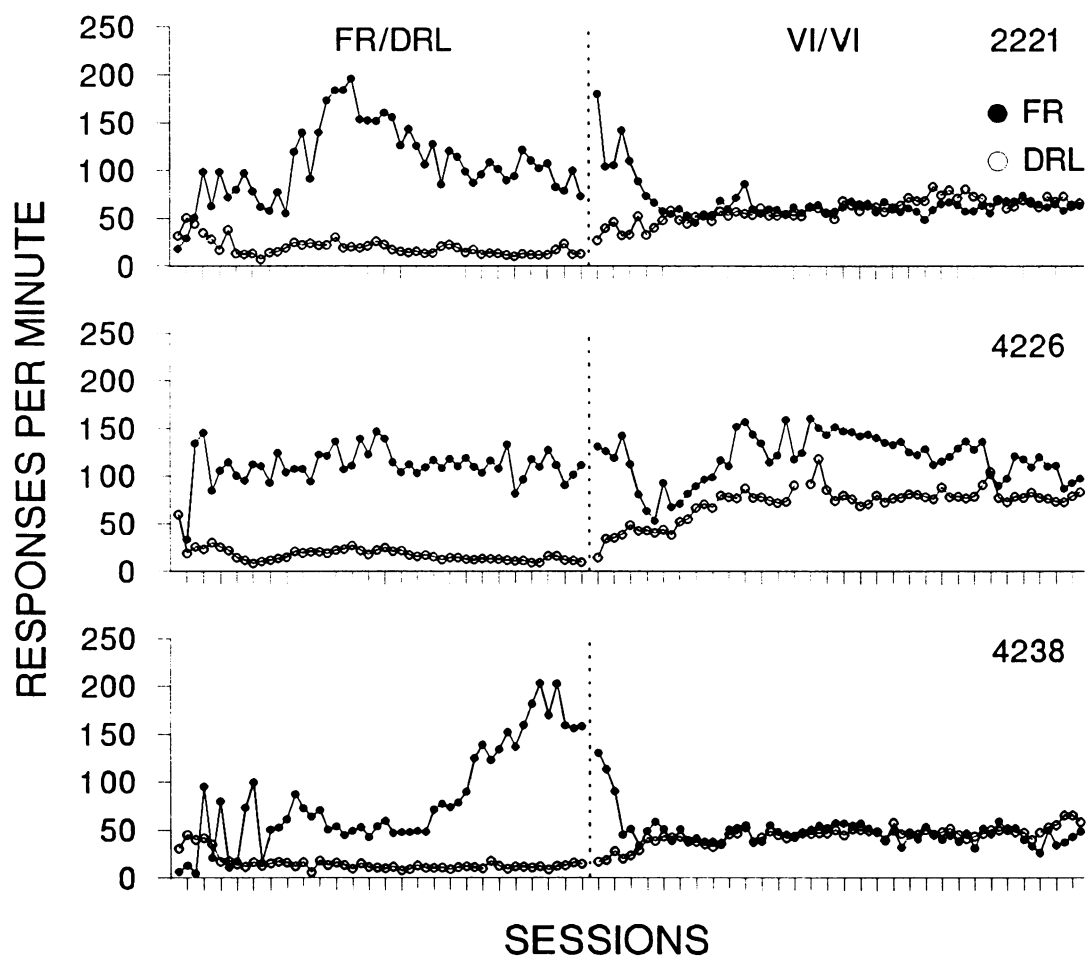


Fig. 2. Response rates for each subject in each session of Experiment 2. The labels at the top of the graph indicate the schedules in effect in the two conditions. The FR/DRL label identifies the differential condition, and the VI/VI label identifies the nondifferential condition. In the VI/VI condition, the data are identified by the schedule previously in effect in the same stimulus condition during the training condition. For Pigeon 4226, FR data for the first session were lost.

tervals, and the mean IRIs for Pigeons 2221, 4226, and 4238 were 33 s, 29 s, and 25 s, respectively. Every 10th IRI was fixed at the mean IRI value. The distribution of responding in successive seconds of these fixed IRIs allowed computation of the quarter-life measure to index patterns of VI responding.

RESULTS

The mean IRIs (with ranges in parentheses) for the last 10 FR and DRL training sessions for Pigeons 2221, 4226, and 4238, respectively, were (in seconds) 38.9 (30.4 to 50.2) and 30.3 (25.5 to 40.3), 36.4 (29.0 to 42.7) and 20.9 (18.0 to 22.9), and 14.7 (12.0 to 17.7)

and 34.2 (28.7 to 45.4). Thus, only with Pigeon 2221 was reinforcement rate close in the FR and DRL schedules.

Figure 2 shows session-by-session response rates of each pigeon. During all but the first few sessions of the differential condition (labeled FR/DRL), response rates were higher under the FR than under the DRL schedule. The effects of the two schedule histories on VI responding differed across subjects. For Pigeon 4226, over the 60 days that the VI schedule was in effect (labeled VI/VI), response rates in the presence of the stimuli previously correlated with the FR schedule were consistently higher than those in the

presence of the stimuli formerly correlated with the DRL schedule. For the other 2 pigeons, VI response rates initially were higher in the former FR condition; however, rates in the two stimulus conditions first converged after a few sessions. Response rates were higher in the former FR condition for 25 to 30 sessions before the rates in the two components became indistinguishable (Pigeon 4238) or higher in the former DRL component (Pigeon 2221).

The VI response patterns in the different stimuli are summarized as quarter-life values in Table 2. (The quarter-life values were calculated as described in Experiment 1.) Patterns of VI responding following DRL and FR training were approximately the same. For each subject, responding generally approximated a more constant pattern (a quarter-life value of .25) with increasing sessions of exposure to the VI schedule. The only exception was that responding of Pigeon 4226 during the VI schedule in the presence of the stimuli previously correlated with the DRL schedule was negatively accelerated (quarter-life values < .25) during the last few sessions.

EXPERIMENT 3

In this experiment, the effects of prior parallel experiences on subsequent VI schedule performance were examined using a different procedure. In Experiments 1 and 2, the parallel experiences with the different schedules were established when the two daily sessions involving the two different training schedules were separated by 6 hr. In Experiment 3, a history of high- and low-rate responding was established by using a multiple schedule in which component schedules controlling high and low response rates alternated several times within each session. This condition was followed by a multiple VI VI schedule.

METHOD

Subjects

Four White Carneau pigeons were maintained at 80% of their free-feeding weights. Water and health grit were freely available in the home cage. Each pigeon had a history of responding under VI and variable-time (VT) schedules.

Table 2

Mean quarter-life values in each component of the multiple VI VI (nondifferential) condition.

| Subject | Component | Session | | | |
|---------|-----------|---------|-----|-----|---------|
| | | 5 | 25 | 50 | Final 6 |
| 2221 | FR (VI) | .38 | .34 | .32 | .23 |
| | DRL (VI) | .33 | .30 | .26 | .27 |
| 4226 | FR (VI) | .28 | .31 | .22 | .23 |
| | DRL (VI) | .32 | .20 | .16 | .15 |
| 4238 | FR (VI) | .23 | .28 | .29 | .24 |
| | DRL (VI) | .28 | .23 | .22 | .24 |

Apparatus

An operant conditioning chamber (Gerbrands Model G7311) was housed in a sound- and light-attenuating enclosure (Gerbrands Model G7210). The chamber contained a response key centered on the work panel 25.5 cm from the floor that was operated by a force of 0.16 N. The key was transilluminated red or green except during reinforcement and blackouts, when it was dark. During all conditions, reinforcement was 3-s access to mixed grain in a hopper located behind an aperture (5 cm by 5 cm) centered on the midline of the work panel, with its lower edge 8.5 cm from the chamber floor. During reinforcement, the aperture was illuminated by white light. Two white houselights were located adjacent to one another in the center of the chamber ceiling and were illuminated continuously during each session except during reinforcement and blackouts. White noise and a ventilating fan masked extraneous sounds. Electromechanical programming and recording equipment was located in an adjacent room.

Procedure

Each pigeon first was exposed to a multiple (tandem VI FR 10) (tandem VI DRL 5-s) schedule. In each tandem schedule, at the end of the VI requirement, the first response produced the FR or DRL schedule and completion of the FR or DRL requirement yielded access to food. The stimuli in the VI and FR or DRL schedules were identical within a component. The two multiple schedule components, described hereafter as the FR and the DRL components, respectively, were correlated with transillumination of the response key by green or red lights. The components alternated and were 15, 30, or 45 s in duration.

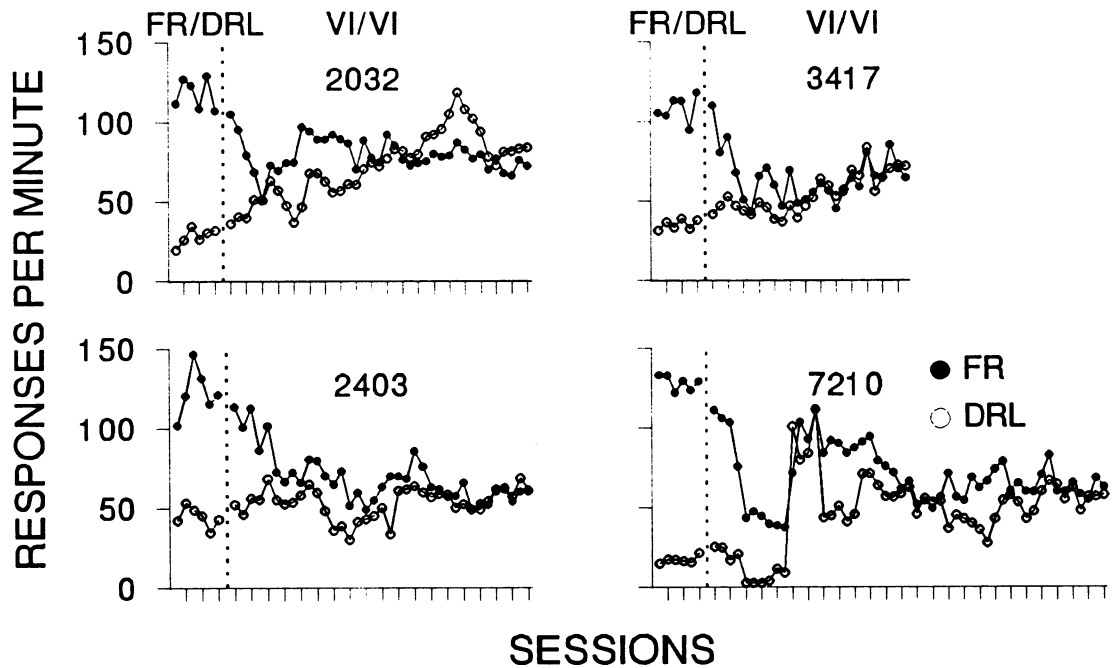


Fig. 3. Response rates of each subject during the last six sessions of the multiple tandem schedule (FR/DRL) and each session of the multiple VI VI schedule (VI/VI). The data are labeled according to the terminal component of the schedule in effect in either component in the training condition.

They were separated by a 15-s interval, during which the chamber was dark (blackout). For Pigeons 2032 and 2403, the nominal mean value of the VI schedule was 300 s; for Pigeons 3417 and 7210, the nominal mean value was 100 s. The VI schedules were constructed from the constant-probability distribution described by Catania and Reynolds (1968).

Following stable performance on the multiple tandem schedule, the FR and DRL components were removed. Thus, the schedule was changed to a multiple VI 300-s VI 300-s schedule (Pigeons 2032 and 2403) or a multiple VI 100-s VI 100-s schedule (Pigeons 3417 and 7210), and responding again was stabilized. In both conditions of Experiment 3, responding was considered stable when the mean response rate during a six-session block differed by no more than 3% from the means of the first and last three session blocks within the block of six sessions. Single daily sessions terminated after 60 min.

RESULTS

The reinforcement rate in the two components is shown in Table 3. Except for

Pigeons 2032 and 2403 in the multiple tandem schedule condition, the reinforcement rate in each component was approximately equal in both the tandem VI FR and VI DRL components and in the two VI components that replaced them. Reinforcement rate increased somewhat when multiple VI VI was in effect.

Figure 3 shows session-by-session response rates of each pigeon in each multiple schedule component during the last six sessions of the multiple tandem schedule (labeled FR/DRL) and each of the multiple VI VI (labeled VI/VI) sessions. The multiple tandem schedule controlled high and low response rates in the FR and DRL components, respectively. Following introduction of the multiple VI VI schedule, response rates in the former FR component initially were higher than those in the former DRL component. Over successive sessions, the response rates in the two components converged to differing degrees in different subjects. This convergence resulted from both a decrease in the former FR component and increases in the other component. Despite this convergence, response rates in the former FR component remained higher than in the other component in almost all

Table 3

For each subject, reinforcers per hour in each component of the multiple (tand VI FR) (tand VI DRL) (labeled mult FR DRL in the table) and in the multiple VI VI conditions of Experiment 3. Each value is the average of the last six sessions of each condition. In the multiple VI VI row, the labels FR and DRL describe the tandem schedule in effect in the indicated component prior to the VI schedule. Deviations of reinforcers per hour from nominal schedule values are the result of sampling limits during the last six sessions.

| Condition | Pigeon 2032 | | Pigeon 2403 | | Pigeon 3417 | | Pigeon 7210 | |
|-------------|-------------|------|-------------|------|-------------|------|-------------|------|
| | FR | DRL | FR | DRL | FR | DRL | FR | DRL |
| Mult FR DRL | 8.2 | 11.5 | 13.9 | 7.0 | 24.1 | 26.4 | 27.0 | 29.6 |
| Mult VI VI | 12.8 | 13.8 | 14.5 | 15.0 | 32.8 | 32.2 | 35.6 | 35.2 |

multiple VI VI sessions for Pigeon 7210, for all except the last few for Pigeon 2403, for the first 14 for Pigeon 3417, and for the first 20 for Pigeon 2032. Only Pigeon 2032 exhibited consistently higher response rates in the former tandem VI DRL component when the experiment terminated.

GENERAL DISCUSSION

These experiments illustrate the establishment and decline of the effects of performance on past reinforcement schedules on responding in the presence of a current schedule. Although in general the effects were similar to those obtained by other investigators using nonhuman subjects, they differed in an important way. The present results were obtained when an individual subject received parallel training on both high- and low-rate generating schedules in the presence of different stimuli. Thus, the history effects may be said to be under stimulus control, in that the different rates in the presence of the same contemporary schedule were controlled jointly by the stimulus and the previous schedule correlated with that stimulus. These results raise other questions concerning the definition, assessment, and generality of reinforcement-schedule history effects.

Within the present context of schedule performance, history effects can be characterized as transition states (Sidman, 1960). As such, history effects cannot be expected to persist indefinitely. The perseverative influence of past reinforcement contingencies at the expense of control by current ones, assuming the organism's behavior has contacted the present ones, would be counter to the malleability of behavior and its adaptability to the present environment. Although

there may be a few isolated experimental examples of such behavioral inflexibility, they are not the rule in a more general context of behavioral adaptation. Of interest in this and other experiments on reinforcement-schedule history effects is not that the effects may diminish over time but that they persist as long as they do.

The study of schedule history has been described primarily in terms of the influence of past high- or low-rate responding on subsequent performance. Immediately previous responding may not be the only distal source of behavioral control, however. For example, Weiner (1969) found low-rate FI responding by humans who had any history of DRL training, even if FR training intervened between the DRL training and the FI test schedule. Pigeons in the present Experiment 1 were exposed to DRL and FR schedules simultaneously; however, the effects of DRL training were controlled by the stimuli present during that training. This finding seems to qualify Weiner's data suggesting that any experience with DRL schedules subsequently might control low-rate FI responding.

Differences in schedule parameters (such as the example of reinforcement rate described in the introduction), response topographies, organismic variables (e.g., deprivation), and stimulus conditions all must be considered when assessing the influence of the past on present responding. Behavior maintained by different contingencies may be differentially resistant to change (e.g., Nevin, 1974, 1979). For example, Lattal (1989) found that responding controlled by contingencies designed to produce low and high response rates were differentially susceptible to disruption by other events. In a similar way, the "strength" of behavior maintained by different training

schedules (like those in the present experiments) may contribute to the transition effect. Thus, a part of the history effect also may be related to the strength of prior responding.

Another question is that of where to look for history effects. Response rates and patterns are the most common measures, but other techniques and indices also may prove useful. The historical effects of FR and DRL schedules on FI responding of pigeons appear to be like those reported for rats by Urbain et al. (1978) and Wanchisen et al. (1989). The effects on VI response rates of high and low response-rate histories are similar to those reported by Poling et al. (1980) for rats. The effects found in the present experiments differed from those of Nader and Thompson (1987) for pigeons in that the differences in VI rates as a function of the training conditions in Experiments 2 and 3 seemed to be more persistent. Nader and Thompson's change in location and color of the response key when the VI schedule was introduced may have hastened the convergence of rates in their VI schedules.

There is mixed evidence that the previous schedule affects subsequent FI response patterns in nonhuman subjects. A template of FR response patterns seems to overlay characteristic FI response patterns more precisely than does a template of DRL responding. That is, the characteristic break-and-run pattern controlled by FR schedules also occurs on FI schedules (e.g., Schneider, 1969; Wanchisen et al., 1989). In addition, the temporal distribution of reinforcers in FR and FI schedules tends to be similar in that reinforcers occur at regular intervals in both. By contrast, DRL responding is more even and reinforcers tend to occur at aperiodic intervals. However, neither the results of Poling et al. (1980) nor the present data support such an analysis. Urbain et al. (1978) reported more scalloping following DRL than following FR training. Unlike the finding of Urbain et al., the patterns of responding during the FI schedules in Experiment 1 did not differ reliably as a function of reinforcement-schedule history.

History effects may occur in more subtle ways than in terms of their effects on rates and patterns of responding. For example, Nader and Thompson (1987) detected a history effect on VI schedule performance only when chronic doses of methadone were given

(see also Barrett, 1986). In the present Experiments 1 and 2, we examined interresponse time distributions at various points before and after introducing the VI and FI schedules to assess historical effects of reinforcement schedules on a more molecular scale. Consistent differences in IRT distributions were not manifest as a function of FR versus DRL training. Nonetheless, this type of analysis, and that of Nader and Thompson, suggest alternative ways of detecting the influence of past reinforcement contingencies on current responding.

The present results also relate to the generality of history effects. The data in previous experiments are restricted to those generated by ratio and DRL training schedules. Experiment 3 demonstrated some further generality of historical effects by using tandem schedules with a VI schedule component. These tandem schedules equated reinforcement rate and generated reliably different response rates in the two components of the training schedule. Poling et al. (1980) proposed that constraints on responding by the subsequent schedule may affect the course of history. Thus, a VI schedule requires consistent responding throughout the IRI if reinforcers are to be maximized. By contrast, according to Poling et al., because of the temporal regularity of reinforcer availability, FI schedules allow less regular responding during the IRI without decreasing reinforcer rates. Poling et al. therefore suggested that FI schedule performance is more likely to be influenced by historical variables than is responding on VI schedules. A comparison of the results of Experiments 1 and 2 generally support the observations of Poling et al. and Nader and Thompson (1987) that FI performance is affected more by historical schedules than is VI performance. However, the generality of this conclusion is constrained by the use of only FR and DRL training schedules and by the fact that reinforcement rates were not equated between the conditions of Experiments 1 and 2.

At present, it is not possible to predict the extent or ubiquity of reinforcement-schedule history effects, but the conditions under which they occur can be analyzed further. Previous investigations indicated the effects of sequences of exposure to rate-controlling schedules of reinforcement on different organisms. The

present experiments indicate that similar reinforcement-schedule history effects occur when individual organisms receive simultaneous, parallel exposure to different reinforcement schedules in the presence of different stimuli. These effects offer additional evidence of the interplay between experience and current contingencies. The complexity of the interplay, however, does not mean that historical variables should be described as capricious and beyond control; instead, such complexity offers an opportunity to isolate the mechanisms that result in the reflections of past experience in current behavior.

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